

## Microbial Control of Weeds

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### Microbial control of weeds – Status

Microbial control of weeds has been in practice now for about 40 years. During this period, about 26 exotic pathogens were deployed as classical biocontrol agents in seven countries and 11 native pathogens registered or allowed for use in 13 bioherbicide products in five countries. When viewed in the context of national and worldwide weed-control needs, several classical biocontrol pathogens have played a primary and decisive role in controlling a few high-profile exotic invasive weeds (e.g., *Puccinia chondrillina* - skeletonweed, *Chondrilla juncea* in Australia; *Entyloma ageratinae* [*E. comopsitarum*] - Hamakua pa-makani or creeping Croftonweed, *Ageratina riparia* in Hawaii-USA; and *Uromycladium tepperianum* - Port Jackson willow, *Acacia saligna* in South Africa). In comparison, only three bioherbicide pathogens have achieved a measure of success in the marketplace: Collego, re-registered as Lockdown (*Colletotrichum gloeosporioides* f.sp. *aeschynomene* for northern jointvetch, *Aeschynomene virginica*); Chontrol and Myco-Tech Paste (both *Chondrostereum purpureum* for stump-treatment to prevent regrowth of several broadleaved trees and shrubs); and Sarritor (*Sclerotinia minor* for dandelions, *Taraxacum* spp.).

Classical biocontrol has two significant advantages over bioherbicides: it is almost exclusively public funded and public policy-driven and is not dependant on the client/customer to purchase and use it. Conversely, bioherbicides that typically consist of native pathogens do not face the same regulatory burden of proof that an exotic pathogen must bear. Whereas the latter must satisfactorily address the sole and inflexible criterion of host specificity, the bioherbicide should satisfy overall safety to nontarget plants, animals, man, and the environment on a somewhat flexible, case-by-case basis.

It has been said that rate of success of microbial weed control (i.e., projects that came to a useful end) is insignificant. However, I would argue that the 39 agents and products that have been implemented resulted from about 100 weed-pathogen projects (39% fruition rate; 39 over four decades). This is a high rate of return given that the number of naturally occurring pathogens suitable for development is small and finite.

### Types of agents, weeds, and technologies

The preponderant microbial weed control agents in use are fungi, with rust fungi leading the way (total 17), followed by coelomycetes (9; *Colletotrichum*, *Phoma*, *Pleospora*, and *Septoria*), hyphomycetes (3; *Alternaria*, *Cercospora*, and *Phaeoramularia*), agaricomycetes (2; *Chondrostereum* and *Cylindrobasidium*), and one each in ascomycetes (*Sclerotinia*), oomycetes (*Phytophthora*), and smuts (*Entyloma*). So far, only one bacterial pathogen has been registered as a bioherbicide, and a plant virus-based bioherbicide is under EPA review for possible registration. More emphasis on bacteria and viruses is needed.

These agents are used in a variety of weed-control situations such as in golf greens, grain fields, lawns, natural areas (urban and rural lands, woodlands, forests), orchards, timber plantations, rangelands, and waterways. The parasitic weed dodder is also a bioherbicide target. Efforts to develop bioherbicides for weeds in row crops (e.g., soybean, tomato), a major market, have failed for reasons explained below.

The existing microbial technology (submerged fermentation, solid-state production, and biphasic systems) in private industries is adequate to meet the demands of mass-production of aerobic, culturable fungi and bacteria. Likewise, formulation technology, both proprietary and published, has been adopted for different types of pathogens to produce liquid concentrate, wettable powder, dust, paste, and pellet products. These formulations are developed with the intent to enable application with conventional application tools, such as tractor- or aircraft-mounted sprayers, a mower with mow-and-smear capability, backpack sprayers, and hand application. As a rule of thumb, the need for special application tools is a deterrent to the adoption of microbial control agents into existing weed-management programs.

### Why is microbial weed control underutilized?

High among the reasons are the dual challenge of efficacy and consistency of bioherbicide pathogens, the realities of the marketplace, and inadequate support to expand and accelerate the rate of progress of this field. Efficacy and consistency of performance can be a major constraint as bioherbicides reach the field-testing stage. Often this challenge results from inherent characteristics of the weed-pathogen systems: many pathogens simply do not have the capability (virulence/aggressiveness, rate of reproduction, and/or environmental fitness) to control weeds that typically have a variety of survival strategies. While basic research and technical innovations may help overcome problems of efficacy and consistency, historically it has not been possible to undertake the necessary comprehensive studies except on a few bioherbicide pathogens that have reasonable economic prospects in the marketplace. Genetic engineering could provide

solutions; in fact, some workers have proposed the use of genetically engineered pathogens for weed control. However, presently no genetically modified pathogen has been approved for weed control.

Competition from chemical herbicides is the strongest cause of underutilization of microbial herbicides. The marketplace is replete with broad-spectrum chemical herbicides that serve the needs of a clientele that is accustomed to chemical herbicides; inevitably, bioherbicides must go up against this tough competition. Targeting niche markets is one solution, namely development of bioherbicides for markets where chemical herbicides are unavailable or unacceptable. For example, the introduction of Collego was timely when 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) was withdrawn from use as a rice herbicide. Presently, Sarritor has an enviable market position with the banning of the “cosmetic use” of pesticides for lawn care in Canada and some U.S. regions. Chontrol and Myco-Tech Paste could also gain significant market shares as alternatives to chemical herbicides. It is noteworthy that Sarritor, Chontrol, and Myco-Tech Paste contain pathogens with broad host-ranges, which should make these bioherbicides more marketable than a highly host-specific bioherbicide that is effective against a single weed target.

### **Regulatory framework, support structures, and some constraints**

The current regulatory system in place, namely the APHIS-TAG (Technical Advisory Group for Biological Control Agents for Weeds) review process for the introduction and use of exotic pathogens and the EPA-FIFRA biopesticide registration process are adequate, in my opinion. The latter, with which I am more familiar, is registrant-friendly; the tiered testing protocol and the ability for case-by-case risk analysis provide a clear roadmap to develop registration data. For instance, a broad host-range of a pathogen (the taxon) is not necessarily a deterrent as long as the strain used as the active ingredient is adequately tested to assure safety to nontarget plants and there are safeguards such as lack of spread, lack of vectors, limited persistence, distance from targets, etc. Similarly, members of fungal genera that are known to produce several toxins may be registerable if the strains in question are atoxigenic or produce no mycotoxins.

Petition to release and use exotic biocontrol pathogens in the United States must be reviewed and recommended by the TAG and approved by APHIS-PPQ. In addition, these agents may require EPA registration since their use for weed control invokes a “pesticidal claim.” Since I have not dealt with TAG for many years, I will refrain from commenting on the TAG review process. A related issue is the interstate movement of registered bioherbicide pathogens. Currently, the registrant should petition APHIS for a permit(s) to ship the bioherbicide pathogen across state lines. This is in addition to the need to register the bioherbicide through Departments of Agriculture in each state where it will be used.

Assessment of risks to threatened and endangered (T&E) species is integral to both the EPA registration and TAG processes. The testing of T&E species could be onerous if not for a case-by-case approach to risk assessment. Collecting or acquiring T&E plant material for testing is in itself a regulated activity. It would be helpful if there were recognition of the fact that weeds, particularly exotic invasive weeds, are a more serious threat to T&E species than the possible threat from microbial weed control agents. The latter may in fact help the recovery and preservation of T&E species.

Besides the EPA and APHIS support structures, the IR-4 Biopesticide Program has been invaluable to the development of bioherbicides. IR-4 provides grants for biopesticide efficacy testing, is a clearinghouse for biopesticide information, and facilitates EPA registration. Likewise, the USDA-NIFA-Small Business Innovation Research program enables small businesses to develop and market microbial pesticides.

### **Way forward: the needs**

As we look to increase the use of microbial weed control agents, it is essential to strengthen networking and communication among the research, regulatory, industry, and user groups. Networking is critical to clear some misperceptions of pathogens. For example, there is the vague and unfounded fear of pathogens, the “pathophobia,” which is expressed in exaggerated claims of mutability of pathogens, unforeseen consequences from genetic recombination, unpredictable nontarget attacks, dangers of mycotoxins, environmental buildup, etc. While all of these concerns should be addressed before approval of pathogens, they should not be a de facto basis to deny consideration of pathogens.

Other top issues include the need for more SYs to replace retiring scientists and to strengthen research in newer areas of pathogen biology, weed biology, and fermentation, formulation, and application technologies. Resources are needed to address both basic and applied sciences, perhaps through a NIFA grants program for research and development of microbial biocontrol agents. Yet another means of funding is also urgently needed to incentivize the adoption of microbial biocontrol by users, possibly modeled after the Natural Resources Conservation Service-Environmental Quality Incentives Program (NRCS-EQIP).

Finally, the science of microbial weed control needs to move beyond the search & screen stage to a pathosystem-level exploration of physiological and molecular effectors of pathogenicity and plant death.